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The urgent need for seismic protection of police and fire stations is based on the fact that these facilities are essential during emergencies and that current building codes in many jurisdictions are not adequate to meet the challenge of seismic risk. Effects of the Alaskan Earthquake of 1969 are cited to emphasize the need for improved management planning and programming. Several key factors identified from the experience of the earthquake are listed. Among these is the need for scatter-site development of government buildings, including fire and police stations, and mobile units to afford a greater survival potential. This report, outlining the problem of seismic safety, includes: a chart showing the critical functional areas of police and fire stations during an earthquake emergency; special vulnerabilities; design guidelines for seismic safety; and several practical approaches to implementation of these designs. Faculty cost impacts which take into consideration variables for existing facilities are described as well as several design studies, including an actual example of a police station.

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Earthquakes
Structural design
Risk
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Cost analysis
Fire departments
Management planning
Construction management

b. Identifiers/Open-Ended Terms

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Anchorage

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MANAGEMENT NEEDS SUMMARY:
SEISMIC DESIGN FOR POLICE & FIRE STATIONS

Development of this publication was supported under subcontract from the AIA Research Corporation, pursuant to *Grant No. ENV — 76 — 80695* from the Research Applied to National Needs (RANN) Program of the National Science Foundation (NSF). The opinions, findings, conclusions, and recommendations herein are those of Public Technology, Inc., and do not necessarily reflect the views of either the AIA Research Corporation or the National Science Foundation.

FOREWORD

Robert H. Oldland can provide sobering testimony to the effects of an earthquake on a community. In 1964, he was the City Manager when Anchorage, Alaska, was hit by a major quake that registered 8.5 on the Richter Scale.

It is a fact that 39 of the 50 United States can experience disastrous earthquakes. The great Alaskan earthquake on Good Friday, 1964, dealt metropolitan Anchorage a devastating blow that will affect the community for years to come. Many structures, both public and private, literally were shaken into piles of unrecognizable rubble. Events at that time provided a dramatic illustration of the need for improved seismic and safety design standards.

The city government would have been part of the homeless, but the relatively new Public Safety Building and its access routes remained essentially unscathed. Because of damage to the City Hall, day-to-day government operations and recovery efforts were moved to the fire and police headquarters facility. It could just as easily have been a building casualty, as was the case with many other public and private structures that did not survive.

As search and rescue operations, damage surveys, and recovery operations took place, the need for improved management planning and programming became evident. Several key factors were identified from the experience:

1. Existing building and related structural codes must be updated to recognize the unexpected hazard of earthquake shock. The potential prolonged stresses accompanying the initial quake (approximately five minutes in Anchorage) can be a serious problem, but so are the multiple, intermittent after-shocks which often follow.

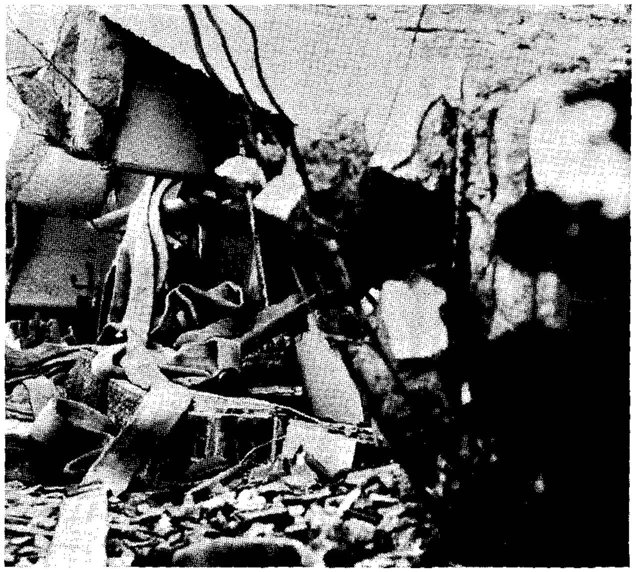
2. A government's public safety network of buildings, life-saving equipment, radio/dispatch facilities, mobile units, and on-duty personnel are important in day-to-day operations, but become vital in times of disaster and emergency.

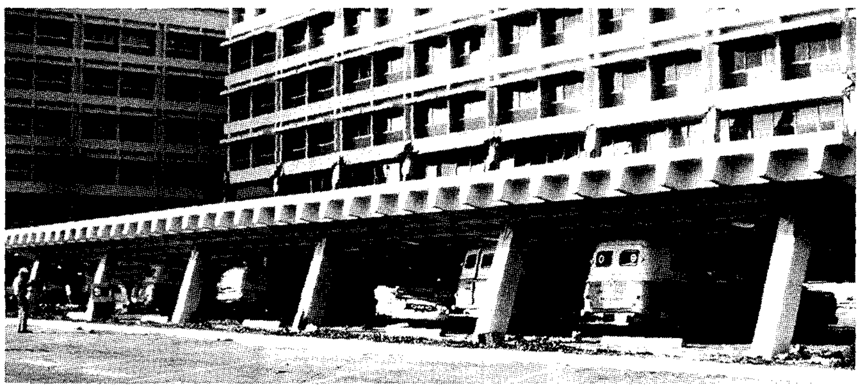
3. Scattered-site development of key governmental buildings, including fire and police stations, substations, and mobile support units, would afford more survival potential in earthquake prone areas.

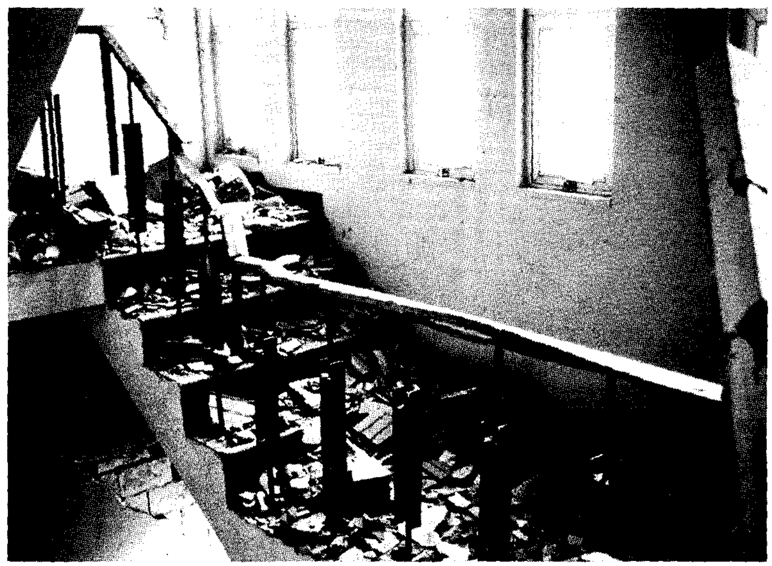
In many cities, earthquakes are not the only major hazards facing police and fire stations. Floods, hurricanes, tornadoes, and civil disturbances may pose equal or greater risks. It is important to realize that earthquake risk can be objectively considered together with these other hazards. Many building design measures can provide protection for multiple hazards.

Seismic safety design standards, location planning, and a working knowledge of the potentially devastating effects of an earthquake are all part of the earthquake preparedness for a city. Knowing the devastating power of earthquakes, it is clear that seismic preparedness is not something to be put off or ignored.

Robert H. Oldland
City Manager
Joliet, Illinois







The photos above show the type of earthquake damage that has occurred to police and fire facilities. Much of this could have been prevented through adequate seismic safety design. Often the cost of such safety improvements is very reasonable, especially if considered from the beginning of a project.

THE PROBLEM

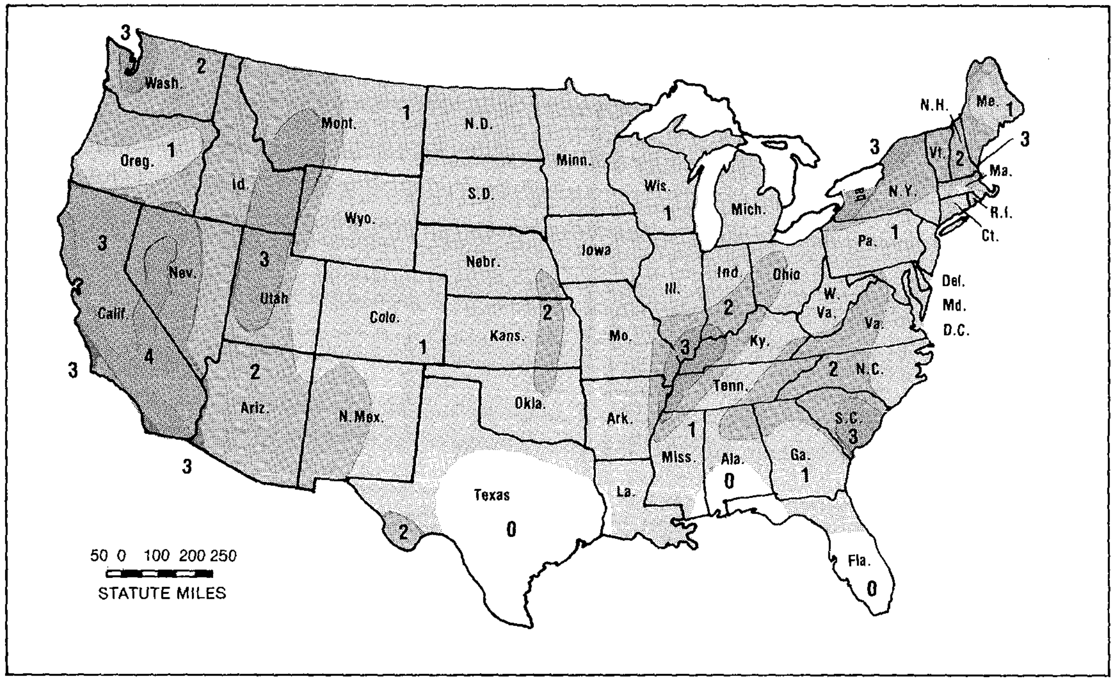
While 39 of the 50 United States can experience earthquakes, it is also true that without a proven ability to predict earthquakes—especially those which may occur away from the heavily studied West Coast—we just do not know when serious earthquakes will occur in most parts of the country. The seismic risk map reproduced below indicates the relative potential for damage from quakes in various parts of the U. S. by placing a value of 0 to 4 on a series of risk zones. A zero indicates no risk. For cities in zones 2, 3 and 4, the earthquake hazard is quite real and should be a major concern to managers responsible for planning and design.

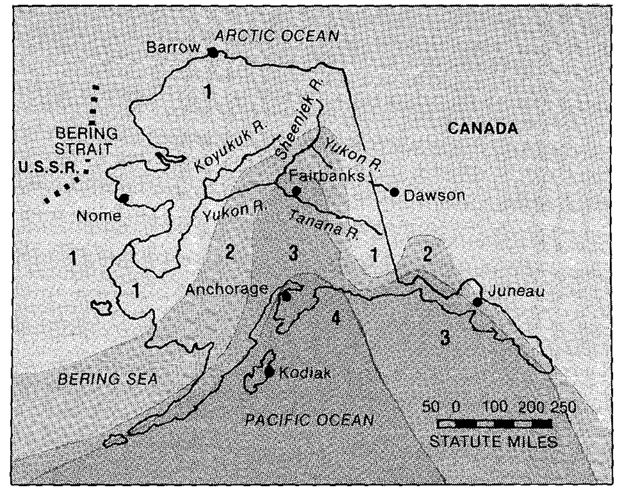
Damage to police and fire stations can have several causes: structural damage from ground motion; damage from the collapse of taller adjacent structures; slapping together of adjacent structures; failure of the supporting capacity of the ground beneath the building; and earthquake-induced landslides, floods, and tidal waves. One of the most important and least frequently considered sources of damage to police and fire stations involves shifting or collapse of equipment, doors, partitions, ceiling fixtures, and other non-structural components in the building.

The problem of seismic safety should be one of genuine concern to local officials, despite what may have been heard about the likelihood of earthquakes. Consider the following facts:

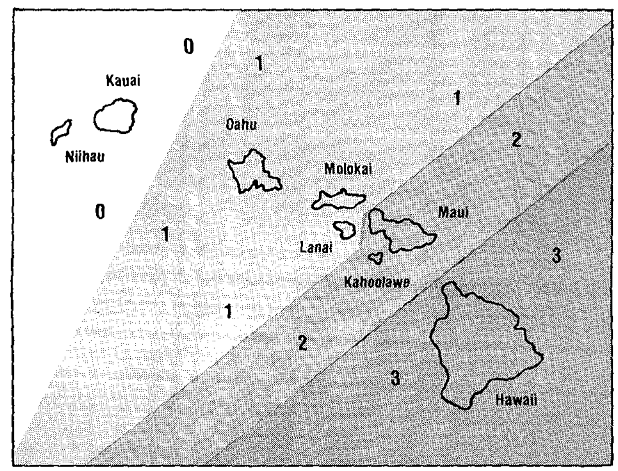
- *Risk of severe earthquakes is real.* This is true in many of the most populated areas of the country.
- *Potential damage is increasing.* This has come about in large part because of increased urban concentrations and development.
- *Seismic protection of police and fire stations is not adequately provided.* Current building codes in many jurisdictions simply are not adequate to meet the challenge of seismic risk.
- *Eastern and midwest codes frequently provide inadequate seismic protection of the building structure.* No codes that we have seen provide adequate protection of all non-structural building elements —a very important omission.
- *Seismic protection is feasible.* With current construction techniques, and with appropriate design, it is possible to protect facilities so that they can remain operational following an earthquake.
- *Seismic protection costs are affordable.* Design studies described later show that the cost of protection in new police and fire facilities is practical, especially when considered along with other hazards, such as floods, hurricanes, tornadoes, and civil disturbances. Existing facilities, however, particularly those constructed of unreinforced masonry, may be expensive to fully protect through retrofit measures. Increasing the current level of protection, though, may be quite practical.
- *Codes provide minimum standards.* Designers can go beyond the codes when codes do not require sufficient protection to building components or do not address specific situations.
- *Structural safety is not the only important aspect of seismically safe construction.* Hung ceilings, partitions and other interior construction, HVAC, electrical and plumbing systems as well as furnishings must receive seismic safety consideration.

Seismic Risk Map of the United States





STATE OF ALASKA



STATE OF HAWAII

KEY:

- ZONE 0—No damage
- ZONE 1—Minor damage; distant earthquakes may cause damage to structures with fundamental periods greater than 1.0 second; corresponds to intensities V and VI of the M.M.* Scale.
- ZONE 2—Moderate damage; corresponds to intensity VII of the M.M.* Scale.
- ZONE 3—Major damage; corresponds to intensity VIII and higher of the M.M.* Scale.
- ZONE 4—Those areas within Zone No. 3 determined by the proximity to certain major fault systems.

*Modified Mercalli Intensity Scale of 1931

Source: Seismic Risk Map of the Conterminous United States—after S.T. Algermissen, "Seismic Risk Studies in the United States," *Proceedings of the Fourth World Conference on Earthquake Engineering* (Vol. 1, pp. 19-27), Santiago, Chile, 1969.

CRITICAL FUNCTIONAL AREAS

Not all functional areas within police and fire stations have the same importance in terms of seismic protection, nor are all areas equally vulnerable to earthquake damage. Functional areas such as communications centers are highly susceptible to seismic damage, and their continued operation during an earthquake disaster is of extreme importance. For other functional areas, however, such as evidence storage in a police station, the need for continued operation may have a low priority, but it is still vital to protect the contents for later use. Overall, to minimize the cost of seismic protection, and to assure that vital functions are protected, priorities must be set for protection of individual functions within each police and fire station.

Charts which follow show an evaluation of various functional areas in police and fire stations. Not all stations will contain each of these areas. Also, individual cities may choose to allocate their priorities somewhat differently. The charts, however, can be used as a starting point in a city's assessment of the need to protect various functions performed in its planned or existing stations.

Studies of past earthquake damage have shown that fire and police stations, like chains, are only as strong as their weakest links. Otherwise sound fire stations have become inoperative because doors to appraatus areas have racked and failed to open. Stations have become inoperative when regular electrical service failed and emergency generators either had not been provided or were damaged or disrupted. Each police and fire station can have unique strengths and weaknesses from an earthquake standpoint, and these require special attention. Once basic requirements are set to achieve adequate protection of the most critical operational functions, then the jurisdiction can take steps to develop and evaluate the feasibility of specific design solutions for protecting the most important of the functional areas.

SEISMIC CRITERIA / FIRE STATION FUNCTIONAL AREAS	VULNERABLE TO SEISMIC DAMAGE						PROTECT CONTENTS	CONTINUE FUNCTION			KEEP SECURE	RANK			
	STRUCTURAL DAMAGE	ELECTRICAL DISRUPTION	HVAC DISRUPTION	PLUMBING DISRUPTION	EQUIPMENT DISRUPTION	SPECIAL RISK TO OCCUPANTS		CRITICAL	HELPFUL	NO NEED		VULNERABLE	PROTECT	CRITICAL	SECURE
ADMINISTRATION (AD)															
Lobby/Reception	•	•	•			•				•		•			
Clerical Area	•	•	•			•				•		•			
Staff Offices	•	•	•							•					
Conference Room	•	•	•							•					
OPERATIONS (OP)															
Apparatus Room	•	•	•	•	•	•	•	•			•	•	•	•	•
Communications Room	•	•	•		•	•	•	•			•	•	•	•	•
SUPPORT FUNCTIONS (SF)															
Hose Care Area	•	•	•	•	•		•		•			•	•		
Equipment Storage	•	•	•		•		•			•	•	•	•		•
Dormitory	•	•	•			•	•			•		•	•		
Locker Area	•	•	•	•		•				•		•			
Day Room	•	•	•						•			•			
Food Prep/Dining	•	•	•	•		•			•			•			
Training Room	•	•	•							•		•			
Exercise Room	•	•	•			•				•		•			
MECHANICAL (ME)															
Mechanical Room	•	•	•		•		•	•			•	•	•	•	•
Emergency Generator Area	•	•	•		•		•	•			•	•	•	•	•
VEHICLE (VE)															
Maintenance/Repair	•	•	•		•	•	•	•			•	•	•	•	•
Gas Pumps	•	•			•	•	•	•			•	•	•	•	•
Fuel Tanks	•				•	•	•	•			•	•	•	•	•
Motor Court	•				•		•		•				•		
EXITWAYS															
Halls/Stairs/Poles	•	•	•			•	•	•				•	•	•	
Exits	•	•					•	•			•	•	•	•	•

SEISMIC CRITERIA

POLICE STATION FUNCTIONAL AREAS	Vulnerable to Seismic Damage: Structural Damage	Vulnerable to Seismic Damage: Electrical Disruption	Vulnerable to Seismic Damage: HVAC Disruption	Vulnerable to Seismic Damage: Plumbing Disruption	Vulnerable to Seismic Damage: Equipment Disruption	Vulnerable to Seismic Damage: Special Risk to Occupants	**Protect Contents**	Continue Function: Critical	Continue Function: Helpful	Continue Function: No Need	**Keep Secure**	Rank: Vulnerable	Rank: Protect	Rank: Critical	Rank: Secure
ADMINISTRATION (AD)															
Lobby/Reception	•	•	•			•				•		•			
Clerical Area	•	•	•			•				•		•			
Staff Offices	•	•	•							•					
Conference Room	•	•	•							•					
Toilets	•	•	•	•						•					
OPERATIONS (OPS)															
Briefing Room	•	•	•			•			•			•			
Detective Operations	•	•	•			•				•		•			
Interview/Detention	•	•	•							•					
Juvenile Operations	•	•	•			•				•		•			
COMMUNICATIONS (CO)															
Communications Center	•	•	•		•	•	•	•			•	•	•	•	•
Electronic Maintenance	•	•	•		•		•	•			•	•	•	•	•
Switching Equipment	•	•	•		•		•	•			•	•	•	•	•
RECORDS (REC)															
Central Records	•	•	•			•	•			•	•	•	•		•
Data Processing	•	•	•		•	•	•			•	•	•	•		•
PRISONER PROCESSING (PP)															
Sallyport	•	•			•				•		•	•			•
Booking	•	•	•						•		•				•
Temporary Holding	•	•	•		•	•	•		•		•	•	•		•
Detention	•	•	•		•	•	•	•			•	•	•	•	•
EVIDENCE (EV)															
Receiving/Processing	•	•	•		•					•	•				•
Evidence Storage	•	•	•		•		•			•	•	•	•		•
Crime Laboratory	•	•	•		•	•	•		•		•	•	•		•
Property Storage	•	•	•		•		•			•	•	•	•		•

SEISMIC CRITERIA

POLICE STATION FUNCTIONAL AREAS (continued)	Vulnerable to Seismic Damage: Structural Damage	Vulnerable to Seismic Damage: Electrical Disruption	Vulnerable to Seismic Damage: HVAC Disruption	Vulnerable to Seismic Damage: Plumbing Disruption	Vulnerable to Seismic Damage: Equipment Disruption	Vulnerable to Seismic Damage: Special Risk to Occupants	**Protect Contents**	Continue Function: Critical	Continue Function: Helpful	Continue Function: No Need	**Keep Secure**	Rank: Vulnerable	Rank: Protect	Rank: Critical	Rank: Secure
SUPPORT FUNCTIONS (SF)															
Library	•	•	•			•				•					
Resource Center	•	•	•			•				•					
Locker Areas	•	•	•	•						•		•			
Exercise Room	•	•	•							•		•			
Day Room	•	•	•	•						•					
WEAPONS (WE)															
Armory	•	•	•		•	•	•	•			•	•	•	•	•
Gun Maintenance	•	•	•							•	•	•			•
Firing Range	•	•	•		•		•			•		•	•		
MECHANICAL (ME)															
Mechanical Room	•	•	•		•		•	•			•	•	•	•	•
Emergency Generator Area	•	•	•		•		•	•			•	•	•	•	•
VEHICLE (VE)															
Vehicle Maintenance/Repair	•	•	•		•	•	•	•			•	•	•	•	•
Garage	•				•		•			•		•	•		
Gas Pumps	•	•			•	•	•	•			•	•	•	•	•
Fuel Tanks	•				•	•	•	•			•	•	•	•	•
Helicoptor Pad	•				•		•		•		•	•	•		•
EXITWAYS															
Halls/Stairs	•	•	•			•	•	•				•	•	•	
Exits	•	•				•	•	•			•	•	•	•	•
Elevators	•	•			•	•			•			•	•		

SPECIMEN SEISMIC CRITERIA CHARTS *(Examples Only)*

These charts, taken from the Design Guidelines, show some of the potentially critical functional areas of police and fire stations during an earthquake emergency and their special vulnerabilities. Throughout the documents, charts and checklists are provided to facilitate evaluation of specific seismic protection needs.

DESIGN GUIDELINES FOR SEISMIC SAFETY

AIA Research Corporation, assisted by Public Technology, Inc. and several architectural and engineering firms, has now developed a set of seismic safety design guidelines for police stations, fire stations, and emergency operating center located within police and fire stations. This work was financially supported by the National Science Foundation/Research Applied to National Needs Program. *Seismic Safety Design for Police and Fire Stations* is the result of a year-long study by AIA Research Corporation (AIA/RC) which included case studies for incorporating seismic provisions in various types of police stations, fire stations, and emergency operating centers.

From the outset, AIA/RC recognized the importance of practical constraints to implementation of seismic provisions. Cost was a major concern, as was the recognition that design features included for earthquake protection could not be allowed to impair normal station operations. Public Technology, Inc. supported the AIA/RC study by developing and convening meetings of a User Requirements Committee (URC) consisting of representative police, fire, emergency medical, disaster preparedness, construction and city management officials; and architects and engineers. Since these were representatives of primary end users of any design criteria developed during the project, the architects and engineers were an important part of the URC. The user group sought to assure a practical end-product from the research effort. They were concerned that the design guidelines could be applied successfully in areas of high and low seismic risk, in large and small cities, to new and exisiting construction, and implemented within a practical budget.

The Design Manual which resulted from this effort, *Seismic Safety Design for Police and Fire Stations*, is a compendium of design checklists, guidelines and supporting information. Sections of the Design Manual may be used for the design of a police station, a fire station, an emergency operating center within a police or fire station, or to review the safety of existing facilities and the feasibility of seismic safety retrofit. Subject coverage within the Design Manual is shown in the accompanying chart.

Subject Coverage of AIA/RC Design Manual

1. POLICE AND FIRE STATIONS AND E.O.C.'S.
   - Normal vs. disaster operational requirements and related functional and space relationships, specific personnel and equipment needs, critical areas.
   - General and specific design checklists and considerations.
   - Case studies which discuss the feasibility of seismic safety design and estimated associated costs.
   - Apparent future trends in types and levels of services provided and technologies for effective service delivery.
2. GENERAL SEISMIC DESIGN CONSIDERATIONS.
   - Seismic design of building components and various types of building equipment and systems.
3. SEISMIC SAFETY FOR SPECIALIZED POLICE/FIRE STATION EQUIPMENT.
   - Descriptions of vulnerable critical specialized police and fire station equipment and recommendations for reducing hazards.
4. EXISTING FACILITIES: RETROFIT/RENOVATION.
   - Discussion of potential value of retrofit of existing facilities for seismic safety.
   - Description of evaluation methodology which will aid analysis of existing stations for the feasibility of seismic retrofit.
5. RELATIONSHIP OF SEISMIC HAZARDS TO OTHER HAZARDS.
   - Specific, non-seismic hazard considerations and protective measures.
   - Process for integration of multiple hazard protection into design of police and fire stations.
6. ADDITIONAL DOCUMENTATION AND RESOURCES.
   - Listing of publications used in the research effort and their availability.
   - Descriptions of additional projects, documents, etc., developed by the project team which can provide additional information or aid for local seismic design efforts.

IMPLEMENTATION

Both new and existing public facilities can benefit from incorporation of essential seismic design features which can be considered immediately. Several practical approaches to implementation are discussed below.

Existing Facilities

Most police and fire stations which will be in service over the next several decades have already been built. Many of these—particularly older stations—may not have been constructed to meet adequate seismic safety standards. It has been an important part of this project to develop a practical methodology to evaluate the feasibility of retrofit modifications to essential existing structures within the current inventory of police and fire stations. To retrofit existing facilities, a jurisdiction's management and design staff should consider several factors.

For the jurisdiction, decision criteria include: dollar value of the station versus retrofit cost; whether or not the station fits in with planned departmental needs and expansion plans; added cost of operational disruption during retrofit; flexibility of the station building to accept new types of services and equipment.

Design issues which will influence what will be done include existing conditions and deterioration of the building and site, hazardous building alterations, operations disruption from retrofit, and costs of required modifications. The evaluation methodology presented in the AIA/RC Design Manual can be used to find answers to the design issues. An evaluation recording form is supplied along with explanations of what problems to look for in each component category. A walk-through of each building is required for this evaluation.

Members of the User Requirements Committee expressed great concern about the difficulties experienced when trying to interest their jurisdictions in seismic design. It may be difficult in such situations to win approval of an independently conducted retrofit evaluation of existing stations. An alternative approach is to tie the evaluation in with another project that will be applied to the same stations (for example, during an energy conservation study, or during a municipal police or fire protection study or master emergency planning exercise). Such concurrent programs can accomplish multiple goals at a cost savings over separate projects and can ensure that the preliminary steps toward improved seismic safety will be taken.

New Facilities

Using the Design Manual, designs for police and fire stations and Emergency Operating Centers can be developed taking into consideration normal and disaster functional and equipment requirements which determine critical seismic design needs. Checklists from the Design Manual allow comparison between hypotetical and actual situations, functions, and facility needs.

Seismic safety design for new police and fire stations and emergency operating centers can be accomplished as an intergral part of the normal programming, design, and site selection process. Seismic safety is but one of the safeguards which must be built into those facilities and should be treated in that context.

Seismic design criteria, when applied as part of an overall hazard reduction effort, may actually cost less than if considered as a separate safeguard. This multi-hazard design approach is described in the Design Manual. The architect should evaluate with the client all of the possible hazards to a given facility and prioritize the critical safety needs. Especially effective in reducing the incremental additional costs of providing seismic protection are safety criteria designed in to reduce damage from hurricanes, tornadoes, nuclear blast, and some security and energy conservation design elements.

FACILITY COST IMPACTS

Costs for implementing seismic design measures in police and fire stations depend on numerous variable local factors and specific building characteristics. Many of these variables are described below.

Actual Risk: Based on the Seismic Risk Map (page 5), the risk zone in which a jurisdiction is located will influence overall local preparedness needs, seismic safety implementation plans, and, therefore, implementation costs.

Local Geology, Topography, and Hazards: Specific buildings site conditions influence costs. Local geologic and topographic conditions, including faults sub-surface soils and water, flood plains, etc, must influence decisions on station placement and protection. Also, proximities to dams, dikes, bodies of water, hazardous materials storage and other potential hazards must also be considered.

Building Characteristics: The shape, size, and internal configuration of stations and the materials and methods of construction have a major impact upon implementation costs for seismic design criteria.

Local Building Codes: Costs for achieving a higher level of seismic protection in public safety buildings through improved building codes are reduced when the existing local code has already included certain seismic safety provisions. Many jurisdictions in high risk zones however have no seismic safety provision in their codes.

Existing Facilities: Existing facilities present special problems since seismic retrofit requirements will vary tremendously and costs for modifications may be much greater in existing construction than for new construction. Some significant problems are listed in the accompanying chart.

Cost Variables for Existing Facilities

- *Deterioration*—of the structure, foundation, equipment, etc.
- *Alterations*—which have reduced safety or will incumber efforts to retrofit and renovate; lack of flexibility.
- *Inadequate Codes* — in force when the station was built which make the structure and basic components too expensive to retrofit for earthquake safety.
- *Inherently High Cost to Retrofit* — based upon the type of construction and building system, their age, and the practicality of making improvements.
- *Climate* — characteristic local weather conditions influence construction needs, which in turn affect seismic safety approaches and those costs.
- *Down Time for Buildings* — retrofit activity may force building closure for a period of time. Costs for relocation of employees and services will add to the overall cost of modifications.
- *Other Hazards* — needs to increase the resistance of existing buildings to hazards other than earthquakes may significantly increase costs and reduce the practicality of retrofit for earthquakes alone.

DESIGN STUDIES

Several design studies were conducted during the course of the project to explore use of seismic safety criteria in the design of police, fire, and emergency operating centers within police or fire stations. These, plus an actual example (police station) have placed the estimated addition costs for seismic protection of new facilities within a range of 2% to 10% of construction costs.

Police Station

This design study, derived by protecting an existing, non-seismic design, resulted in additional estimated costs for seismic safety of about 10.1%. The station was redesigned into a functionally continuous but structurally divided facility of three parts, one of which, rigorously designed for seismic safety, houses all critical functions.

Fire Station

Adapted from a station design utilizing a jurisdiction's current seismic code requirements to the increased protection requirements for maintaining an operational capacity this design utilized value engineering for systems optimization and resulted in a 2.6% added cost for seismic improvements. Mechanical and electrical design improvements were the most expensive measures required.

Emergency Operating Center

An E.O.C. design study was conducted for a combined police/fire facility for a small city. Costs were prepared for two types of emergency operating centers: (1) A combined-use E.O.C. which would be used also during normal operations. It accounted for 10% of total building costs and optimized use of building space. (2) An independent (emergency use only) E.O.C. That unit cost less without combined use equipment, but the requirement for separate space increased the building size 11%, and its cost to 8.8% more than with the combined use E.O.C.

Central Police Headquarters, *North Charleston, South Carolina*

The City of North Charleston, South Carolina, is building a new City Hall which will contain the police department headquarters. Recommendations by the Police Chief, L. Edward Simmons — a member of the URC — to include seismic design considerations resulted in changes which appreciably upgraded overall facility safety for natural disasters. The estimated additional cost for seismic design, at 7%, fell within an acceptable range considering North Charleston's relatively high degree of seismic risk.

The foregoing examples of seismic design costs indicate that significant cost increases may be expected in a range of about 2% to 10% when seismic criteria are utilized in station design. Costs, however, will vary as does risk, specific local needs, and levels of safety provided by current codes in force in each jurisdiction. Although there is no magic formula to predict seismic design costs, it has been determined that such costs can be reasonable and the resulting benefit for the community well worth the expenditures.

ACKNOWLEDGEMENTS

Public Technology, Inc. wishes to express its sincere appreciation to those project team members and participants who guided its development and provided assistance, documentation advice, and encouragement in producing and reviewing its results.

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